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ABSTRACT

This paper describes the instructional devices and innovations developed and used by Gerbert D'Aurillac (ca. 947-1003), who was elected Pope Sylvester II in 999, and their subsequent impact on education in medieval Europe. The effect of prevailing thought on Gerbert's innovations is also described. The first section examines the historical context and provides biographical information on Gerbert. Gerbert's pedagogy is described in the second section, including the planar abacus, celestial spheres, the celestial teaching machine, and the monochord. The influence of Gerbert is addressed in the third section, including the failure of his instructional devices and innovations to gain widespread use after his death. Rediscovery of his work by a subsequent pope, Alexander III, is discussed in the fourth section. Possible parallels in the 20th century are considered in the final section, including the use of mechanical teaching machines and programmed instruction in the 1950s and 1960s, as well as recent initiatives for the use of computers, the Internet, and other electronic devices. (Contains 40 references.) (MES)

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The Y1K situation:

Gerbert's instructional devices, their influence, and possible parallels to the present

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The year 1999 marked the 1,000th anniversary of the election of Gerbert d'Aurillac (ca. 947-1003) to the papacy as Sylvester II. In most works concerned with the history of the popes, Sylvester is remembered mainly for being the first Frenchman to become pope (Mann, 1925; Attwater, 1939; Walsh, 1980; Cheetham, 1992), having been born somewhere in Aurillac. Additionally, most popes of the early mediæval period are perhaps remembered principally as being creatures of the Holy Roman Emperor (Binns, 1967; Ullman, 1972). While the degree of Sylvester's political autonomy as pope may be debated, his accomplishments in education, and his fame as an educator predated his tenure as pope. Gerbert was a renowned educator in his time, and in no small way, an innovator in the use of instructional devices (Darlington, 1947).

Although there has been considerable pressure recently, both in schools and in universities, for computers and other electronic devices to be integrated into instruction, the process, not to mention the merits of such approaches, has been questioned and criticized in some quarters (Baer, 1972; Postman; 1992; Stoll, 1995). It might appear that because of the apparent novelty and uniqueness of such technological developments, the questions and problems inherent in implementing instruction using computers and the Internet are peculiar to this century, and that we are traversing an uncharted path. While such electronic technology did not exist in the past, there were other developments and innovations in instructional technology, and a study of the factors leading to their success or failure may possess relevance to present-day attempts to have modern innovations adopted.

This paper describes the instructional devices and innovations developed and used by Gerbert d'Aurillac, and their subsequent impact on education in mediæval Europe. In turn,

the effect of prevailing thought on Gerbert's innovations is also described. To be sure, Gerbert's instructional innovations were noted and recognized as such by his contemporaries. Richer, who served as Sylvester's chronicler wrote, "He broke with all tradition in his devising of charts, models, and instruments for demonstration to his students and for handling by them..." (in Lattin, 1961, p.18).

Teaching aids and manipulatives in education did not originate with Gerbert. The Roman educator Quintilian (Marcus Fabius Quintilianus) was famous during his lifetime in the first century A.D., for using such aids as ivory letters to help teach concept formation of letters of the alphabet. Quintilian's methods were known and practiced to a greater or lesser degree subsequently. Moreover, there are numerous examples of earlier Greek devices that were used as teaching aids (Buck, 1989). Gerbert's innovations extended far beyond the utilization of teaching aids, however.

Context

The state and methods of education in Gerbert's time differed considerably from what exist today. There was no formal state-run or private educational system of the sort that we have presently. The semi-formalized education system that had evolved in the Western Roman Empire had largely disappeared after its collapse in 476 A.D., with the exception of the curricula of the *trivium* (grammar, logic, and rhetoric), and the *quadrivium* (arithmetic, geometry, astronomy and music), which were taught primarily by the Church. Mathematics (arithmetic and geometry) and astronomy were especially important to the church, as these skills were necessary to ascertain important religious days and events (King & Millburn, 1978). Additionally, some classical authors such as Cicero, Virgil and Ovid continued to be

read and studied in some quarters, although not everyone approved of the study of pagan writing (Binns, 1967).

If one were of royalty or nobility, then tutors could be hired. Most families were poor, however, and if one were to become "upwardly mobile" in society at that time, then education was an essential ingredient. Most education was under the purview of the Church, and through entering a path towards holy orders, many males gained an education. Some clerics possessed more knowledge and better teaching practices than others and those with a good reputation often attracted students from great distances. While it was possible for a student to travel around the countryside to different scholars, this process was expensive, time consuming and inefficient. By the tenth century, a number of Cathedral schools had been established in Europe, usually in larger towns and cities. The reputation of each school varied on the basis of the reputation of the individual instructors, and on how the schools were administered. Many such Cathedral schools later evolved into universities (Rashdall, 1936).

It is believed that Gerbert first attended Cathedral schools in what is now France (Riché, 1987). Gerbert was evidently an exceptional student, and his achievements led to his further education. His quest for knowledge beyond the norms of the time led to a part of Gerbert's life that proved to be controversial. He was sent to study for a time in what is now Catalonia, where it seems most likely that Gerbert received instruction from Muslim scholars (Martorell, 1985; Riché, 1987). It is not known exactly what instruction Gerbert received in Catalonia. It is likely that much of his instruction was in mathematics and astronomy, since Gerbert later wrote much about the subjects, and it appears that much of this knowledge was then unknown in western Europe (Lattin, 1985; Moehs, 1985).

After returning from Spain, Gerbert taught in several Cathedral schools, directed the Cathedral school at Rheims, and also served as Abbot of the great Italian monastery at Bobbio for a short time (Lattin, 1985; Riché, 1987). Besides being well read, Gerbert was considered an excellent teacher, having come to the attention of the King of France, and several Holy Roman Emperors, including the young Otto III, whom he tutored (Lattin, 1985; Riché, 1985; 1987). Moreover, Ditmar, Bishop of Merseberg wrote about Gerbert's teaching, "He was very well versed in discerning the courses of the stars and surpassed his contemporaries in his knowledge of different arts" (Ditmar). Gerbert attributed his success in teaching to a seemingly simple principle, "I teach what I know, and I learn what I do not know" (in Mann, 1925). The veracity of this statement is borne out in Gerbert's surviving letters which indicate that he wrote to other scholars requesting copies of books and manuscripts (Sylvester II; Lattin, 1985). During this time, he gradually rose through the clerical ranks, although this progress and his association with royalty was fraught with much political intriguing.

Gerbert's pedagogy

It was noted previously that Gerbert's teaching relied heavily on the use of teaching aids and manipulatives. His use of such apparatus was motivated by his pedagogical philosophy, which was that simply explaining abstract concepts was not sufficient to ensure understanding. In explaining how he taught rhetoric, Gerbert stated,

> I drew up a diagram of rhetoric on twenty-six leaves of parchment sewed together, and forming in all two columns side by side each of thirteen leaves. It is without doubt a device admirably adapted for the ignorant and useful to the studious scholars in order to help them understand subtle and obscure rules of rhetoric and to fix these in their memory. (Gerbert, 986, in Darlington, 1947, p. 472).

In some respects, Gerbert's pedagogical method is similar to the exogenic style of constructivism as defined by Schunk (1996). In this manner of constructivism, it is believed that the learner creates his or her own concept of what is around them through the manipulation and interaction with representations of the external world. As such, models and simulations may be used to assist learners in their process of creating a construct.

Planar abacus

Gerbert also applied this approach to other subjects of the *trivium* and *quadrivium*. In explaining how to teach multiplication and division, for example, Gerbert wrote in 980, that he designed a planar abacus that could illustrate the concepts of multiplication and division so that a student would not have to grasp the abstract concept initially. The abacus consisted of a large board made by a shield maker. It was divided into 27 columns lengthwise. Each column had several symbols placed in it, probably painted, which represented numbers. Special horn characters were then placed on the symbols to perform either multiplication or division (Sylvester II; Lattin, 1961; Evans, 1977; Vogel, 1985; Riché, 1987).

Since this particular abacus has not survived, nor any of the other abaci of Gerbert's design, there is debate as to whether they served as instructional devices, or were used primarily as calculators. Vogel (1985) contends that Gerbert's abaci probably resembled others of the time that were built following the design and principles of Boethius. To add confusion, it is thought that Gerbert used Arabic numerals, at least to some degree. While it is doubtful that Gerbert introduced Arabic numerals to Western Europe, he was one of the first European scholars to introduce them into the curriculum (Hill, 1915). While an abacus is an essential tool for calculation if using Roman numerals, it is not necessary, though useful, for multiplication and division using Arabic numerals. On the other hand, a planar

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abacus using Arabic numerals can help illustrate the concepts of multiplication and division. Whether or not Gerbert's abaci were designed primarily for instruction rather than for calculation, Gerbert's use of them was unusual for the time, and their use was congruent with his pedagogical philosophy of demonstrating abstract concepts concretely.

Celestial Spheres

Gerbert also devised and used instructional devices for the other subjects of the *quadrivium*. As noted previously, astronomy was considered important by the church to ascertain dates correctly. To be an effective astronomer, one had to recognize particular stars, constellations and their relative positions at certain times. Gerbert concluded that using small celestial globes when describing the cosmos would help students to develop a concept of the cosmos and astronomy. Although celestial globes were mentioned as early as 550 B.C. by Thales of Miletus, Gerbert stated in 989 that his were designed for instructional purposes rather than for purely astronomical applications (in Lattin, 1961).

While it is not known whether Gerbert constructed celestial globes himself, he describes their construction in great detail. Each consisted of a turned wooden sphere that was first covered with horsehide, then painted blue. The horsehide provided a suitable surface to receive paint. Stars, planets and lines showing their relationships were then added using other colours (Gerbert, 989, in Lattin 1961).

The effectiveness of this teaching aid was realized by many of Gerbert's contemporaries, as several of his letters answer requests for him to provide celestial globes. Indeed, Richer (999) reported that Gerbert eventually stopped responding to such requests as they interfered with his teaching and other duties.

Gerbert also designed a specialized armillary sphere to illustrate further the path of planets and constellations in the cosmos. Unlike a solid sphere, an armillary sphere is hollow and usually comprised of a number of intersecting and concentric rings arranged in such a way that their circumferences form the outline of a sphere. The rings usually represent the trajectories of particular celestial bodies and may also represent a horizon and/or the location of the zodiac. Additionally, there is usually some means of aligning the sphere to the pole star or some other specific, easy-to-identify celestial body (King & Millburn, 1978). The following illustration, probably dating from the fourteenth century, depicts a monk using an armillary sphere and other astronomical instruments as a teaching aids (after a miniature in *Romance of the image of the world*, in Lacroix, 1877, p. 91).

Figure 1. A monk using an armillary sphere as a teaching aid

Celestial Teaching Machine

Although Gerbert's use of celestial and armillary spheres for instructional purposes was novel for the time, another instructional device that Gerbert created was far more

innovative. While most students would gain some understanding about planets, constellations and the zodiac through interacting with teaching aids, the transfer of this knowledge to the actual cosmos was a further step. Traditionally, students were taken outside and shown particular constellations, with the hope that they would eventually recognize particular celestial bodies and patterns based on what they had learned in class and upon what they were shown. Besides preferring his students to create their own concepts, Gerbert's other duties often meant that he did not have the time to conduct such evening classes.

To facilitate the transfer of learning from class to practice, while also not impinging on his time, Gerbert developed instructional devices that could be used by students without the instructor being present. One such astronomical teaching machine is described in detail, although no illustration of it is known to exist. According to Richer (999), Gerbert started with a basic design of an armillary sphere,

> but he fashioned above, on iron and copper wires, the forms of the constellations. For an axis he used a tube through which one looked at the north pole [probably meaning the pole star], and when one looked at this pole the machine corresponded to the sky and all the stars corresponded to the marks of the sphere. (4.52)

That this device was intended to teach is borne out by Richer who wrote, "if a single constellation were known to them [the students] on the sphere they could find the others themselves, and that without the aid of a teacher" (4.52). The idea of a *teaching machine* was novel, especially where a teacher did not have to be present. Nevertheless, there is evidence that some of Gerbert's contemporaries and successors used celestial spheres and possibly the celestial teaching machine as well (Stevenson, 1921; Riché, 1987).

Monochord

Another subject in the *quadrivium* was music, and Gerbert was as innovative with this subject as he was with the others. According to Richer (999), Gerbert showed how the formation of particular notes was related to mathematics. To illustrate this concretely, Gerbert designed a monochord. Such devices consist of some sort of sound box that supports a single string. By plucking the string while placing a finger on it at particular points, one can show audibly and visually, the relationship between tones, semi-tones and harmonics (Riché, 1987). While there is little doubt that monochords had been constructed earlier as musical instruments, Richer's account suggests that Gerbert's use of it solely for instructional purposes was unheard of previously.

Among the numerous titles of works ascribed to Gerbert, is one concerned with the design of organs *Mensura fistularum* [By the measurement of the pipes]. While the work is lost, the title suggests that Gerbert's understanding and teaching of music focused on its mathematical aspects. There are some later accounts that suggest that Gerbert actually designed and had an organ constructed in Rheims. No account from Gerbert's time, however, supports this view (Riché, 1987). Nevertheless, Gerbert's understanding of and approach to teaching music is similar, although on a much simpler level, to the method developed by Schillinger in the twentieth century. He contended that the successful musician (performer and composer) either possessed an innate mathematical sense of music, or had to be taught the relevant mathematics. Schillinger noted that his pupils included George Gershwin, Benny Goodman and Glenn Miller (Schillinger, 1946).

Influence of Gerbert

As Gerbert rose within the church, his role as an educator diminished, ending entirely with his election to the papacy in 999. Although as pope, Sylvester II no longer taught or wrote on educational matters, his stature led to the widespread proliferation of knowledge about his methods and devices. While imitation may be considered the sincerest form of flattery, many of Gerbert's contemporaries were unsuccessful in imitating his methods. In one of his letters written while he was pope (in Lattin, 1961), Gerbert noted that some individuals who attempted to copy his methods and devices did so incorrectly, which resulted in poor instruction at best, or dissemination of incorrect information at worst. Ironically, as pope, Sylvester could do little to address this problem. Sylvester II's term as pope lasted a little over four years, Sylvester dying on the 12th of May 1003.

While he lived, the influence of Gerbert's devices and the resulting method of instruction, in part without a teacher present, appears to have been widespread. Nevertheless, in a little more than 100 years, Gerbert's instructional devices and innovations were largely either forgotten or misunderstood, and in some instances denounced. In large part, the failure of his devices and methods to gain widespread use was because of difficulties in obtaining the apparatus, and also because the use of such devices did not necessarily guarantee that instruction would improve, or even remain at the level it was before their use. Gerbert either fabricated the devices himself, or oversaw their production. While most of the apparatus was simple by today's standards, specialized skills and tools were required to create them, such as a lathe, and such tools and skills were not commonplace.

In every instance, Gerbert created an instructional device from a need that he perceived, either by making an abstract idea concrete, or by providing him with time to do

other things, thereby letting his students discover particular events or facts for themselves. It does not follow that because this approach worked well for Gerbert, it would work the same way for other instructors. Additionally, ignorance and suspicion helped ensure that Gerbert's innovations were not used or adopted (Compayré, 1893).

The best known account of this failure, are the writings of William of Malmsbury, (ca. 1100), who describes one of the abaci designed by Gerbert. From his description, it is apparent that William neither understand how it worked, nor its purpose. Besides contending that Gerbert's abacus did not to have any relevance to mathematics, William concluded that it could only be a special talisman, endowed with powers that enabled Gerbert to use supernatural and diabolical forces to beat his rivals, thereby becoming pope (Hock, 1842; Poulle, 1985). In other words, Gerbert's instructional devices were viewed by William of Malmsbury as "instruments of the devil". While there was some mention made of Gerbert's devices by educators after 1003, it seems that no one claimed to use his methods or devices after William of Malmsbury's condemnation. Nevertheless, some of Gerbert's ideas and methods were later rehabilitated.

Alexander III

A subsequent pope, Alexander III, rediscovered Gerbert's work, and appreciated its educational merit. Before being elected pope in 1159, Orlando Bandinelli had an enviable reputation both as an expert on canon law, and as an excellent teacher (Alexander III). It seems likely that while a teacher, Bandinelli adopted some of Gerbert's material. Although he probably understood Gerbert's use of instructional devices, Bandinelli noted administrative problems which discouraged the use of instructional devices that did not require a teacher to be present. From first-hand experience, Bandinelli saw how some

individuals were being appointed to teaching positions without adequate qualifications, or once in the position, such individuals would sub-contract their teaching to others (Alexander III; Mann, 1925). Knowledge of instructional devices that could be used without the presence of a teacher would likely have led to further abuses of position.

To teach, one was supposed to have earned a *licentia docendi*, but in many instances, these teaching licenses were sold, either for a fixed price, or for a continuing percentage from student fees. When he became pope, Alexander III took action by condemning the practice as being tantamount to Simony (the buying and selling of holy offices). Evidence of this practice subjected the perpetrator to excommunication, a sentence Alexander III passed on several clergy, including some Bishops (Alexander III; Marrou, 1956). In this way, Alexander effectively created a set of conditions that discouraged instruction except by the intended instructor (Alexander III; Mann, 1925).

The stringent administrative policies governing the behaviour of instructors, implemented by Alexander III were carried on and developed further by later popes, such as Honorius III (Rashdall, 1936). An effect of such policies was to encourage conformity to consistent ways instructors taught and regarded the curriculum, a tradition that endures largely to this day. We are now a thousand years removed from Gerbert, so it is perhaps reasonable to ask how knowledge of the innovations and experiences of a mediæval educator is relevant to the present.

Possible parallels

In the decade spanning the mid 1950s to the mid 1960s, there was a prevalent movement in North American education to use mechanical teaching machines, and other approaches following the tenets of programmed instruction (Lumsdaine & Glaser, 1960).

While most of the initiatives arose from a genuine belief that such apparatus could improve both teaching and learning, factors such as cost, no evidence of improved learning, inferior apparatus and subject content, and exploitation of education by the corporate sector, eventually led to the general demise of such approaches. For instance, Sorestad (1963) commenting on the effectiveness of teaching machines wrote, "Unless more scientific experimentation is organized and caried out [to show that this technology and approach leads to learning] there is very little possibility of making any worthwhile assessment of teaching machines or programmed instruction in general" (p. 12). Even a major proponent of teaching machines and programmed instruction, B.F. Skinner, conceded that the goals of commercial enterprises were often at odds with appropriate pedagogy in schools. Commenting on the failure of a commercial firm to develop and market a teaching machine that followed his design exactly, Skinner (1983) wrote, "I had been altogether too innocent. I should have seen that Rheem [the manufacturer] was simply 'waiting to see how the ball bounced'" (p. 237). Other educators did not perceive how teaching machines could be integrated into teaching. When the utility and benefit were not apparent, the criticisms were not charitable. Gilbert (1979) recounting his address to the 1960 convention of the American Psychological Association, stated, "If you don't have a device called a teaching machine, don't get one. Don't buy one, don't borrow one, don't steal one. If you have such a device, get rid of it. Don't give it away, because someone else might use it" (p. 16). The effect of such criticism, coupled with cost, contributed to the elimination of such apparatus and approaches from schools, whether deserved or not.

In a similar vein, there have been many good initiatives within the last fifteen years for the use of computers, the Internet and other electronic devices for instructional purposes. At the same time, there have also been initiatives where the motive has been profit, or apparent

cost reduction by replacing teachers with technology, or simply transforming text-based materials into electronic form without much regard for quality or appropriateness. Such attempts often result in poor instructional material and equally poor methods of instruction. In consequence, many teachers and some educational institutions have become more critical and circumspect, and in some instances, the use of such technology and approaches is being eschewed (Stoll, 1995).

In a more disturbing vein, criticism of using the Internet in schools has grown in some quarters because of the impression that it is comprised mainly of sites containing "inappropriate" materials (Vernadakis, 1998; Cate, 1998). That the Internet actually is comprised primarily of inappropriate sites is unlikely, yet some individuals act as though it is. In a manner similar to the now defunct *Index Expurgatorious*, some software manufacturers are approaching the problem by trying to isolate the student from "inappropriate" sites. Yet such software either blocks sites that are appropriate and useful, or the software does not perform as intended. To be sure, there are sites on the Internet that contain and promote prurient material, and others that advocate racist and other prejudicial views. Nevertheless, there are many sites that do not contain objectionable material, and which may be edifying to students. Moreover, Clyburn (1998) noted that the most common illegal activity occurring on the Internet is fraud. As with educators in the mediæval period, we are left with the question as to whether or not particular material and approaches should be used in practice when they contain potential to either disturb or even harm a student. Given that the debate concerning use of the Internet in schools remains emotional and highly charged, it may help to put matters into perspective by considering what occurred with innovations and materials in the past that were considered equally controversial.

The experiences of Gerbert d'Aurillac reveal that instructional devices can assist teachers to do a better job, if needs are identified and addressed, and if teachers also perceive these needs. At the same time, however, instructional devices are neither a substitute for the teacher, nor are they a magical means for taking any content and transforming it into something that is both interesting and edifying. By not questioning and critically analyzing the initiatives for using computer technology, including the Internet, we may well end up with a Y2K problem in education, much like that reported by William of Malmsbury a millennium before. The merit of current instructional devices will either be misunderstood or lost, and such devices may be seen as evils (Postman, 1992; Stoll, 1995). As in the past, the real losers will not be the technology or the reputation of specific educators, but students and education in general.

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